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**On the identity of *Multiceps multiceps* (Leske, 1780), *M. gaigeri* Hall, 1916, and *M. serialis* (Gervalis, 1845), with a review of these and similar forms in man and animals.** H. F. NAGATY, Faculty of Medicine, Cairo, and M. A. E. EZZAT, Veterinary Pathological Laboratory, Giza.

## INTRODUCTION

The question of the coenuri recorded from man and animals is an important one as these cysts are found in a multitude of tissues including the brain, sometimes with very serious pathological manifestations. Already three cases of coenurosis cerebralis have been recorded from the brain of man and some half dozen authenic cases of other coenuri from different human tissues.

In animals the cysts are important from an economic as well as from a scientific point of view. Economically gid disease caused by *Coenurus cerebralis* takes a great toll of animals yearly, especially sheep, resulting sometimes in heavy financial losses. Other similar coenuri have also been recorded from different tissues of many animals.

In spite of the fact that the name is considered a synonym of *Multiceps* according to the International Code of Zoological Nomenclature, as explained later in the text, we have used the term *Coenurus* throughout this paper to denote the larval form of *Multiceps*. This is done for the sake of convenience and also because the name is so well established in medical and veterinary literature.

The aim of this paper is: (1) To give a full description of each of the coenuri met with in the connective tissue and of its strobilar form obtained by feeding experiments, (2) to compare these with known descriptions of *Multiceps multiceps* and *M. gaigeri* and to discuss their identity, and (3) to differentiate *Coenurus serialis* from the other coenuri. We have also reviewed all coenuri known from man and animals.

## HISTORICAL REVIEW

### (a) Coenurosis cerebralis in Animals

The disease caused by this cestode was probably recognized 500 B.C. by Hippocrates. The first authentic record of the larval form was made at least as early as 1634 A.D. by Scultetus in Germany.

In 1780 Leske named the larval form from the brain of giddy sheep appropriately calling it *Taenia multiceps* because of the presence of many heads in the bladder worm. He recognized the cestode nature of the parasite and described it very completely and figured one of its heads.

In 1782 Goeze used the name *Multiceps* in a generic sense to distinguish the many-headed gid parasite from the single-headed cysticercus form.

In 1786 Batsch gave the name *Hydatigena cerebralis* to the larval form of this cestode.

In 1800 Zeder introduced the generic name *Polycephalus* for *Multiceps* and in 1803 *Polycephalus ovinus* for *Multiceps multiceps*.

In 1808 Rudolphi erected the genus *Coenurus* including in it the causative parasite of gid and giving it the name *C. cerebralis*. This name has become well established in the literature as that of the larval form of *Multiceps multiceps*.

In 1853 Kuchenmeister succeeded in demonstrating experimentally for the first time the entire life cycle of a cestode. He fed *Coenurus cerebralis* to a dog and produced a tapeworm which he called *Taenia coenurus*. He then fed the gravid proglottids of this tapeworm to a sheep and produced in it the early stages of the coenurus in the brain.

In 1905 Stiles and Stevenson considered that the correct generic name for this parasite was *Multiceps* because it has priority over the others and because the generic name *Vermis vesicularis*, previously used by Bloch in 1780, was composed of two words contrary to the International Code of Zoological Nomenclature. Accordingly, Hall in 1910 considered that the correct name of the gid parasite was *Multiceps multiceps* (Leske, 1780), all other names falling as synonyms.

Some recent authors still refer to this parasite as *Taenia multiceps*. This seems to us unjustifiable as it appears advisable and indeed on good basis to restrict the generic name *Taenia* to those cestodes that possess a cysticercus, and the name *Multiceps* to those that possess a coenurus stage, in their life cycles. This view has been previously supported by Stiles in 1905 and even as far back as 1866 by Leuckart who stated that the coenurus is related to the cysticercus as a compound to a simple animal, a sufficient reason for systematists to separate them.

In 1907 Gaiger had two cases in Lahore, India, of a coenurus from the connective tissue of the goat. He regarded these as larval forms of *M. serialis* because of their location in the body. He fed some cyst material to a dog which began passing segments of a tapeworm on the 14th day and was killed on the 31st day. The small intestines were packed with tapeworms varying in length from 1 to 40 cm.

Two years later (1909) Dey reported this parasite from the goat in Bengal, India. In this case the parasites were found in the brain, in intermuscular connective tissue in subcutaneous situations, in the mesenteries, and attached to the peritoneum of the abdominal wall and to the serous covering of the viscera.

In 1916 Hall described as *Multiceps gaigeri* the cestode previously designated by Gaiger as *M. serialis*. The former author based his description on the coenurus from the goat and the tapeworm from the dog sent to him by Gaiger.

(b) Coenurosis other than Coenurosis cerebralis in Animals

*Multiceps serialis* (Gervais, 1845) and *M. serialis* var. *theropitheci* (Schwartz, 1927).
*M. tragelaphi* (Cobbold, 1861).
*M. lemuris* (Cobbold, 1861).
*M. polytuberclosus* (Megnin, 1879).
*M. spalacis* (Moniez, 1880).
*M. brauni* (Linstow, 1902).
*M. glomeratus* Railliet and Henry, 1915.
*M. clavifer* Railliet and Mouquet, 1919.
*M. ramosus* Railliet and Marullaz, 1919.
*M. radians* Joyeux, Richert and Schulmann, 1922.
*M. packii* Christenson, 1929.

At least 14 species of *Multiceps* are recorded in the literature. With a few exceptions, the life cycles of these are not known with the result that descriptions are based only on larval forms and mainly on the morphology of the hooks. While it is possible that a diagnosis of some species can be based on the character of the hooks, for others this is almost impossible on account of the similarity of the hooks and the overlapping of their sizes and numbers on the rostellum.

If critically considered, after a study of the literature and material, many of the species listed below will be found to be identical with others. In this paper it is shown that *Multiceps gaigeri* is identical with *M. multiceps*. *M. packii* was obtained experimentally from a dog by Christenson in 1929 after feeding with a coe-

nurus from the heart of a varying hare. According to Baylis its larval form does not appear to be distinguishable from *M. serialis*. *M. clavifer* Railliet and Mouquet, 1919 also is considered to be identical with *M. seralis*. *M. ramosus* Railliet and Marullaz, 1919, from *Silenus* (*Macacus*) *sinicus*, appears, from a study of its description, to be identical with *M. serialis*, a view also shared by Sandground (1937).

(e) Coenurosis in Man

The most commonly recorded taeniid cysts from human tissues, apart from hydatid cysts, are those of *Cysticercus cellulosae*. *C. bovis* also has been recorded several times, the most authentic cases being that reported by Fonton in 1919, who described the cyst from the mammary gland of a patient who also harbored the adult cestode, and that reported by De Rivas in 1937, who obtained at autopsy hookless Taenia cysts from several muscles of the body. In these cases infections to man have resulted, most probably, from the adult cestode through auto-infection.

Multiple-headed coenuri have also been recorded from the human body. The first authentic case was reported by Brumpt in 1913 in the third edition of his *Précis de Parasitologie*. The material was obtained in 1911 from an autopsy of a Paris locksmith with a history of aphasia and epilepsy. The cysts were found in a lateral ventricle of the brain and another in the substance of the cerebrum. These were diagnosed by Brumpt as *Coenurus cerebralis*.

A second case involving the same species was reported by Culver in 1941, the parasite having been secured from the left ventricle of the brain at autopsy of a native of South Africa. A third case was reported by Clapham where a parasite of the same species was taken from the posterior horn of the lateral ventricle of a 39-year-old salior who had complained of severe headaches for a period of 5 years. A well-developed cyst was obtained at autopsy that seemed to occupy the entire cavity, having grown to fit all the various crevices and diverticula of the situation.

In 1919 Turner and Leiper recorded the first coenurus from the subcutaneous tissues of man. The specimen was sent to them by W. B. Johnson who dissected it out from the subcutaneous tissue overlying the intercostal muscles of a native of Northern Nigeria, West Africa. The cyst was referred by these authors to *Coenurus glomeratus* (Railliet and Henry, 1915) a parasite which normally can develop in various small rodents and which had been originally described from a gerbille of Tunis. The cyst reported by Turner and Leiper measured 2 by 1 cm. in diameter and contained about 35 invaginated heads. The adult stage of this cyst was later found by Chapman (1940) to develop in the small intestine of dogs.

In 1931 Taramelli and Dubois reported the clinical aspects of a case of coenurosis and also gave some account of the morphology of the parasite which was excised by the former author from a subcutaneous tumor, the size of a pigeon's egg, in the right forearm of a native woman at Pinga, in the Eastern Province of the Belgian Congo. These authors, from their study of the hooks of the larval scolices, concluded that they could not be identified with *C. glomeratus* previously recorded by Turner and Leiper. Later on a portion of this cyst was sent to Baylis for identification. The latter author found the number of hooks in eight scolices to vary between 30 and 34. The measurements of the hooks varied from 140 to 155 μ for the large and from 100 to 155 μ for the small. Baylis also gave for comparison some figures of hooks of this species and of *M. multiceps* and *M. serialis*. After a study of the rostellar hooks of this material and a careful comparison of them with those of the larval forms of *M. multiceps* from sheep and *M. serialis* from rabbits, Baylis came to the conclusion that it was impossible to identify the species definitely with either of these forms, as did before him the two Belgian authors Taramelli and Dubois, who suggested that a more complete study of the parasitic

fauna of the Pinga district should be made. Craig and Faust (1943) state that this species may possibly be *C. glomeratus*.

Another case of coenurosis, possibly also involving *C. glomeratus*, was reported by Cannon in 1942 from a 30-year-old African from the same locality as that of Turner and Leiper's case, *i.e.*, Northern Nigeria. The material of this case was a small colorless jelly-like mass, without capsule, obtained by dissection from between the muscle fibers of the lower third of the triceps muscle of the right arm.

Yet another species of coenurus which has been reported so far three times from man is *C. serialis*. The first case was reported in 1933 by Bonnal, Joyeux and Bosch. The subject was a 59-year-old French woman and a lover of dogs. She was found to harbour a palpable oval tumour 9 by 3.5 cm. in diameter in her right buttock. This was dissected out and found to contain a *Coenurus serialis* with numerous scolices. Brumpt, Duvoir and Sainton in 1934 reported the second case who was also a French woman from whom three cutaneous tumors were removed by biopsy and at autopsy. Each of these tumors contained a coenurus of this species. The third case was found at autopsy in the brain of a boy from rural California. This was diagnosed tentatively as *C. serialis* by Johnstone and reported by Faust in 1943.

In an earlier paper one of the present authors (Nagaty, 1940) has reported nine larval cestodes found in man and animals in this country (Egypt).

## MATERIAL

In March, 1943, while making a postmortem at the Giza Zoological Gardens near Cairo on a small Nubian ibex, *Capra nubiana*, about 9 months old and bred at Rishrash Valley, Egypt, one of us found a coenurus cyst. This was about the size of a hen's egg and was embedded in the subcutaneous connective tissue between the muscles behind the right scapula. In April, 1944, specimens that proved to be coenurus cysts were sent separately to each of the present writers by Dr. Ibrahim Elsheik for identification. According to him three cysts, each about the size of an apple, had been secured from a Sudanese sheep about 2 years old. The cysts were embedded in the connective tissues of the muscles of both thighs and at their posterior margin, below the iliacus and near the politeal glands. It will be noted that these coenuri have not been recorded previously in this country from the muscular system of sheep. These cysts have been once recorded other than in this country by Sopikof (1931) in a similar position from the subcutaneous tissue of sheep.

In April, 1944, a hybrid bred in Egypt from a Nubian ibex from the Giza Zoological Gardens and an Egyptian goat was found to be infected with a cyst in the left thigh. This cyst was brought to notice owing to its effect in hindering the free movement of the animal. An operation was made to extract the cyst which was deeply embedded among the muscles external to the femur. The cyst was about the size of a human fist and was covered by the adductor muscles and provided with an adventitious capsule. This capsule was firmly attached to the muscles so that it was not possible to dissect it out intact. Three days later the hybrid died and at autopsy was found to be heavily infected with many cysts in different parts of the body but with none in the central nervous system.

The coenuri were encountered, apart from that found in the thigh, in the following locations: On the left side of the thorax embedded in the intercostal muscles between the last two ribs; on the left side of the neck embedded between the mastoido-humeralis and the splenius muscles; and in the abdomen embedded between the right psoas magnus and the sartorius muscles. All the above-mentioned cysts were provided with a well-developed adventitious capsule. Other cysts were found in the liver, lungs and kidney fat. Those in the first two organs proved on examination to be hydatid cysts and those from the kidney fat to be *Cysticercus*

*tenuicollis*. The brain and spinal cord were carefully dissected but cysts were not found in these locations.

The coenuri obtained from the three sources mentioned above, *i.e.*, the Nubian ibex, the Sudanese sheep and the hybrid proved to be identical.

Other interesting material is a glass jar containing a few cysts kept in the Department of Parasitology, Faculty of Medicine, Cairo, under specimen number 155. These were labelled by Looss as "*Coenurus cerebralis* from the cerebrum of *Ovis aries* from Embabeh (near Cairo)." This material on closer examination by the authors was found to be hydatid cysts.

## FEEDING EXPERIMENTS

Two dogs, previously examined for absence of cestode infection, were fed parts of the cysts from the Zoo hybrid, each receiving about 50 scolices.

Of the infected dogs, one died of distemper after 10 days and no postmortem was done on it owing to pressing circumstances. The other was sacrificed after 40 days from the feeding experiment. The small intestine was infested with a large number of cestodes, mainly in the jejunum. Some of these were examined in the fresh state, others were fixed in 10 per cent formalin and some in 70 per cent alcohol. Those that were intended for staining and mounting were pressed, fixed in 10 per cent formalin and then stained in acetic acid–alum carmine. On comparing the heads of adults obtained from the experimental dog with those from the coenuri mentioned above the present authors came to the conclusion that they are also identical. Moreover examination of mature and gravid strobila reveal some anatomical features which are worthy of record and discussion.

## DESCRIPTION OF THE COENURI

*Size and cyst wall.*—The cysts obtained vary from the size of a hen's egg to that of a man's fist and consist of a transparent vesicle distended by a watery fluid containing some detached heads.

*The heads,* which appear as small whitish bodies, are irregularly scattered in clusters on the internal surface of the cyst. The number of clusters is comparatively large although they are well spaced. Each is composed of many crowded heads squeezed together. This is in contrast to the very few known descriptions of *C. cerebralis* in which the clusters are fewer and their constituent elements not so many. In Clapham's (1941) description of this cyst obtained from the brain of a sailor, she states, however, that, "It was thin walled and there seemed to be no adventitious cyst. The scolices were very numerous. The exact number cannot be stated here as certain portions of the coenurus had been used for sections, but in the material that remained, there were more than 700. They were arranged in groups of varying size—some of the groups contained as many as 70 or 80 scolices, others as few as 10 or 12."

In our material the number of clusters as counted in one of the cysts is 45 and each is composed of 30 to 50 heads. The heads are oval in shape and not exceeding 2 mm. in length by 1 mm. in breadth. Some of the heads are easily detached from the bladder wall and are found in the cyst fluid.

*The rostellum* (Fig. 1, A) is provided with a double crown of hooks made up of two types of equal number, a small and a large. They vary in number from 26 to 32.

*The large hooks* measure from 144 to 198 μ in length, the majority being 184 to 189 μ. They are provided with a well-developed, slightly curved blade. The guard which is exactly in the middle of the total length of the hook is conical in shape when viewed laterally. Its proximal base is broad and tapers towards its distal

end which is rounded. There are two apparent slight protuberances or undulations, one towards the blade and the other towards the handle. The long axis of the guard is at right angles with the long axis of the main body of the hook. Ventrally viewed the guard is circular in outline and of nearly the same diameter as the main body of the hook. The handle is straight with parallel edges showing slight un-

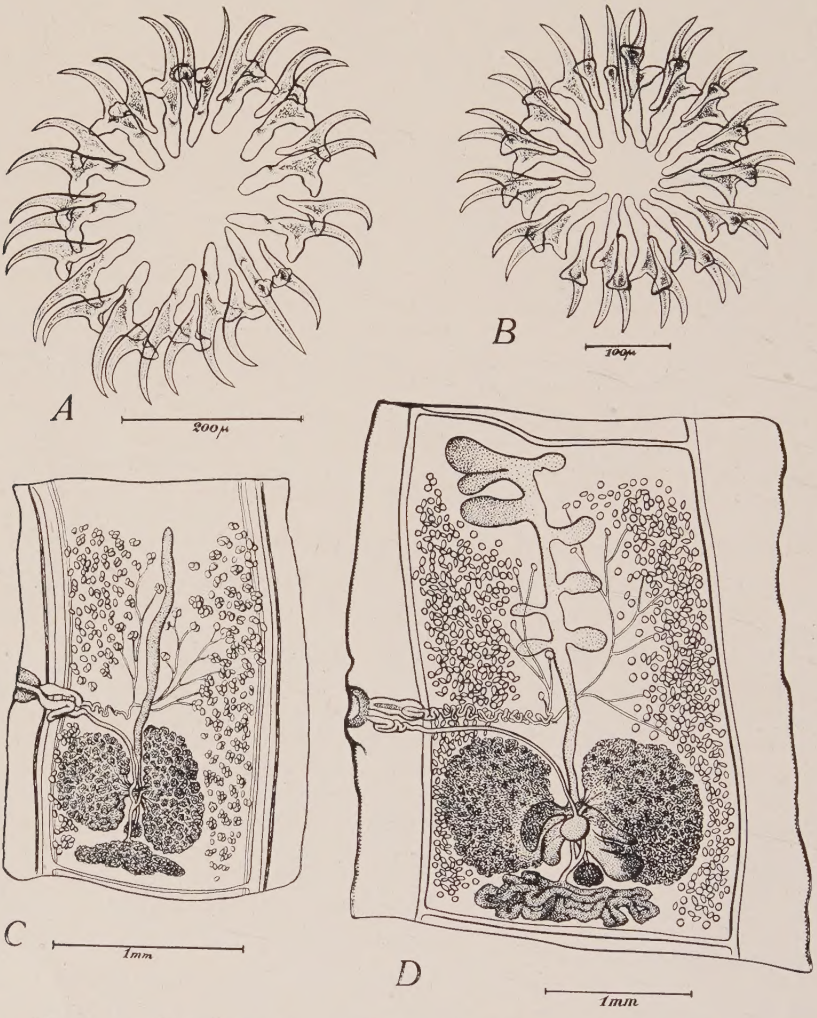


FIG. 1. A—Rostellum from coenurus of the connective tissue. B—Rostellum from the adult cestode. C—Mature segment of *Multiceps* obtained by feeding experiments. D—Pregravid segment of *Multiceps* obtained by feeding experiment.

dulations which are composed of two depressions and seemingly two elevations, the more pronounced of these being found on the dorsal surface closely posterior to the base of the guard. Sometimes this elevation is exceptionally pronounced having the appearance of a hump. These undulations are best seen when the hook is viewed ventrally (Fig. 2, B).

*The small hooks* measure 103 to 135 μ in length, the majority being 121 μ. The blade is more curved than that of a large hook. The guard occupies the fourth

1/6th of the total length of the hook from the tip of the blade. Its general outline when viewed laterally resembles the guard of the larger hook. On careful focussing, however, it shows two tuberosities at its free lateral ends. This is due to the thickening of these ends which terminate in rounded, somewhat conical portions and the presence of a slight depression connecting them and is best seen from a ventral view. The guard is joined to the main part of the hook with a cylindrical base and, ventrally viewed, shows a body approximately three times as broad as the main body of the hook. The handle is short compared with that of the large hook measuring one-third the total length of the hook. It tapers towards its distal end which tilts slightly dorsally when viewed laterally. When viewed from the ventral surface, however, it possesses a rounded distal end and shows a constriction halfway between the tip and the base of the guard.

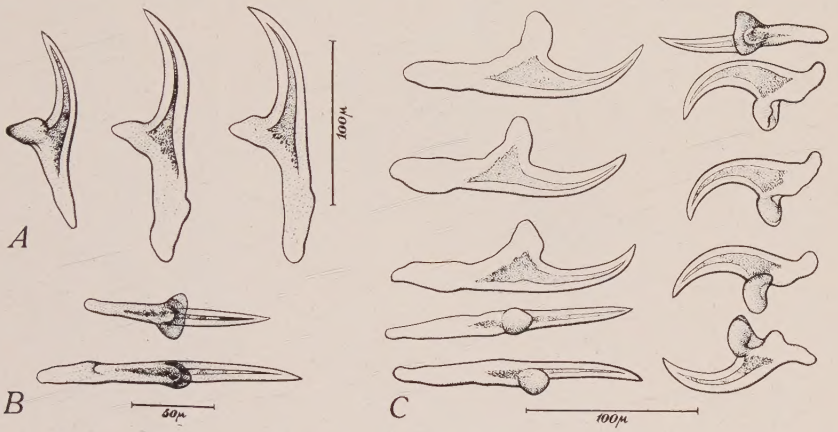


FIG. 2. A—Small and large hooks from rostellum of adult cestode, lateral view. B—Small and large hook from coenurus of the connective tissue, ventral view. C—Small and large hook of *Coenurus serialis* from rabbit.

DESCRIPTION OF THE ADULT OR STROBILAR FORM

The cestodes on which the following description is based were obtained from a dog previously fed experimentally a piece of coenurus containing about 50 heads.

*The size* ranged from 25 to 30 cm. in length and varied in breadth according to the different regions as will be mentioned below.

*The scolex* is globular measuring 750 to 937 μ in breadth and provided with the usual four suckers which measure 250 to 280 μ in diameter. The rostellum measures 327 μ in diameter and, as in the case of the coenurus, is composed of two rows of hooks of different sizes, a row of large and a row of small hooks. The number of hooks in the two crowns was 28 to 30. The large hooks measure 140 to 163 μ and the small hooks 104 to 122 μ and both are similar to those described from the coenuri (Figs. 1, B and 2, A).

The first sign of genital ducts appears at the 44th segment. The genital pores are irregularly alternating and there is a projecting genital papilla.

The Mature Segment

The mature segment (Fig. 1, C) is longer than broad. It measures about 3 mm. in length by 2.4 mm. in breadth in pressed specimens and 2.5 mm. in length by 2.1 mm. in breadth in non-pressed specimens which have been fixed in hot 70 per cent alcohol and cleared in carbolic. The common genital pore is found in the middle of the lateral edge of the segment.

*The male genitalia* are composed of about 200 testes distributed equally on both sides of each proglottis. They occupy a rather restricted elongated area limited laterally by the narrow dorsal excretory canals and, accordingly, some of them overlap the wider ventral excretory canals. They are concentrated anterior to the common genital ducts but do not extend quite to the anterior end of the segment. A comparatively broad area is free from testes except for a few which exist along the median stem of the uterus. Posteriorly the testes limit the lateral borders of the ovary and extend as far as the lateral edges of the vitellaria. The testes on the poral side are separated by the genital ducts into two groups, an anterior and a posterior.

The vas deferens is formed into a closely coiled duct and opens into a well-developed pear-shaped cirrus sac. This ranges in length from 285 to 428 μ and its extention proximally varies in different segments. It may extend well beyond the

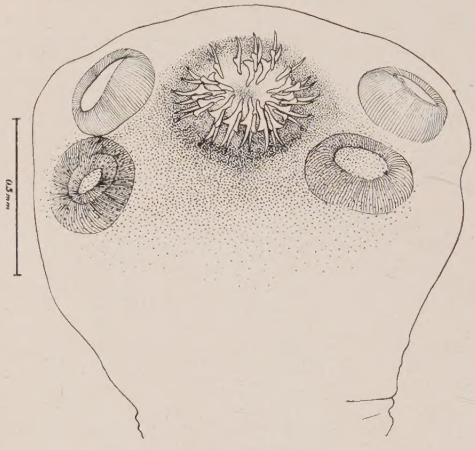


FIG. 3. Head of adult cestode.

excretory vessels internally or may stop at the external wall of the ventral excretory vessel.

*The female genitalia.*—The ovary is bilobed and the two kidney-shaped halves are elongated antero-posteriorly and are situated in the posterior third of the proglottis. They are bounded laterally by testes. The interovarian field is generally oval in outline.

The vitelline glands are pyramidal in shape and the glandular cells are arranged in a tubular fashion forming a reticulum. The anterior limit of the vitellaria is close to the posterior limit of the ovarian lobes and extends posteriorly to the transverse excretory canal. A well-defined and globular Mehlis' gland is found at the posterior end of the interovarian space. The vagina begins at the common genital pore and crosses the excretory vessels, forming a constant S-shaped coil at the beginning of its course. A short distance anterior to Mehlis' gland it shows a slightly dilated receptaculum seminis.

The uterus in this stage is composed of a simple tube directed antero-posteriorly at the mid-longitudinal axis of the segment.

## The Pregravid Segment

The pregravid segment (Fig. 1, D) is larger than the mature one and measures 4 mm. in length by 3.3 mm. in breadth in pressed specimens and 3.2 mm. in length by 2.7 mm. in breadth in non-pressed specimens which were fixed in hot 70 per cent alcohol and cleared in carbolic.

*The male genitalia* are the same as in the mature segment.

*The female genitalia*, however, are in a more advanced state. The ovaries are longer, the vitelline tubules are more voluminous and do not retain their collective pyramidal shape, the receptaculum seminis is more dilated, the uterus extends more anteriorly and develops lateral branches of which a pair can be seen in the inter-ovarian space at this early stage. The common genital pore is not found in the middle of the lateral border of the segment but immediately behind this position.

## The Gravid Segment

The gravid segment (Fig. 4) measures about 11 mm. in length by about 3.3 mm. in breadth in pressed specimens and 6 mm. in length by 3 mm. in breadth in non-pressed specimens fixed in 70 per cent alcohol and cleared in carbolic. The uterus here occupied the greater part of the segment. There are approximately 18 main branches on either side which in turn send out secondary and tertiary branches. The genital papilla is situated at the junction of the third with the fourth fifth of the total length of the segment from the anterior end. The male and the female ducts can be seen leading to and from the papilla.

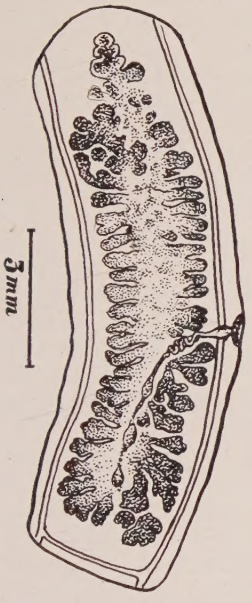


FIG. 4. Gravid segment of *Multiceps* obtained by feeding experiment.

### DISCUSSION

In Hall's description of the two species, *Multiceps multiceps* and *M. gaigeri*, in 1919 we find that the differences mentioned by him in the shape and size of the hooks are not convincing, that these differences are not always borne out by his figures and that they are of a very vague character. This also applies to features of the strobilar form. Comparing Hall's description of *M. gaigeri* with his description of *M. multiceps* and comparing these with our material, structure for structure, as will be done below, we came to the conclusion that the two species are one and the same, and that the previous diagnosis of this material by one of us as *M. gaigeri* was only a tentative one on account of the position of the cyst in the musculature. The position of these larval forms is liable to some variation as, for example, the recording of *M. multiceps* in the musculature of sheep by Sopikof in 1931 and the recording of *M. serialis* in the brain of a monkey by Sandground in 1937 and in the brain of a boy by Johnstone and reported by Faust in 1943.

As regards the adventitious capsule met with in one type of cysts (in the muscular connective tissue) and not in the other (in the central nervous system), considered by Hall a biological difference between *M. multiceps* and *M. gaigeri*, we assume that this is a matter of the reaction of the particular tissue invaded by the cyst. In the central nervous system the neuroglial itssue is capable of forming an adventitious capsule only after a very long time during which the infected host would have died. Undoubtedly the predilection seat in this case is the central nervous system but for some reason or other these cysts do invade other tissues as, for example, when the host is not the typical one.

Comparing the hook, we find in Hall's description of *M. multiceps* that "the large hook possesses a tapering handle with sinuous outline" and that of *M. gaigeri* "with the handle not tapering and either straight or bent dorsally just at the tip." Referring to Hall's figures 43 and 47 of *M. multiceps* and *M. gaigeri*, respectively,

we find that the descriptions do not correspond with these figures and that both represent merely a variation of one species as can be seen from our figures. The small hook of *M. multiceps* is described by Hall as "having long curving handle terminating in a narrow distal extremity" and that of *M. gaigeri* as "having long straight handle terminating in a blunt distal extremity." According to our comparisons the same discussion applies here as has been stated above concerning the large hook.

The appearance of hooks is liable to great variation according to their position in the rostellum as can be seen clearly from our accompanying figures of the two rostella, one from the strobilar form and the other from the coenurus.

Comparing the mature segments, Hall regards as a distinguishing character the extention of the testes posterior to the ovaries almost to the vitellaria and between this and the ovaries in *M. gaigeri* and no such extention in *M. multiceps*. Referring to his figures 45 and 49 of *M. multiceps* and *M. gaigeri*, respectively, we find that this character is not clearly shown and is met with in our strobilar form of one tapeworm as represented by our figures of the mature and the pregravid segments.

Studying the distribution of the testes as mentioned by Hall and comparing his text with his figures we could not arrive at any difference between his supposed two species.

According to Hall's description the cirrus pouch of *M. multiceps* "usually originates in the field lateral to the longitudinal excretory canal and is 315 to 350 μ long" while that of *M. gaigeri* "extends to the median border of the ventral excretory canal and is about 260 μ long." These measurements are contradictory to his description as in the first instance the supposedly short sac is stated to measure 350 μ and the supposedly long one is stated to measure 260 μ, assuming that the proglottids compared are of about the same size. In our observations we noticed that the extention of the cirrus sac, in relation to the longiudinal excretory canals, varies in different proglottids of the same strobila.

Another difference considered by Hall as a striking feature in the transitional proglottids between mature and gravid segments of *M. multiceps* is the almost constant formation of two lateral branches one on either side between the ovary and the vitellaria. We have met with such a formation in our material.

The elongation of the vitellaria along the longitudinal axis of the strobila, which is considered by Hall as a distinctive feature of *M. gaigeri*, is present, according to him, in some segments only and, therefore, we suggest that this character may be due to the state of fixation and pressure of the proglottids.

Apparently, therefore, we have no alternative but to consider Hall's species *M. gaigeri* as a synonym of *M. multiceps* as the latter has priority.

Another point which must be discussed here in connection with the two species mentioned above is the identity of *M. serialis*. Due to the lack of good and accurate descriptions and figures of this species it has been a matter of great difficulty for some authors—Gaiger in 1907, Railliet and Mouquet in 1919, and Southwell in 1923—to diagnose the cysts. Other authors in their investigations, as Baylis in 1932, doubted the possibility of separating the cysts of *M. multiceps* and *M. serialis* on the basis of the hooks or on their morphology in general in the larval stage. Sandground in 1937 recorded from the brain of a monkey a coenurus whose morphology corresponds with *C. serialis*. The author states that his material may represent new evidence challenging the duality of the morphologically indistinguishable species, *M. multiceps* and *M. serialis*, and again, in discussing the specific status of his material, states that it is difficult or impossible to tell apart on morphological grounds the two common species of *Multiceps;* in the few instances where coenuri have been encountered in man it would appear that the specific determination has been arrived at on the basis of the gross form and/or the location of the cyst.

For these reasons the present authors find it necessary to give an accurate description of the larval form of this distinct species, *M. serialis*, as they observed during their examination that it shows marked morphological features, not noticed and recorded by other observers, which can be used to separate it from other coenuri.

### DESCRIPTION OF COENURUS SERIALIS

The material on which the following description is based was obtained from the subcutaneous tissue of a rabbit.

*Size and cyst wall.*—The size is about that of a pigeon's egg or smaller although comparatively large dimensions may be attained. Its wall may present numerous protrusions and invaginated scolices giving the cyst a characteristic appearance. These scolices are irregularly scattered and do not show a definite arrangement in clusters.

*The head* is provided with a double crown of large and small hooks numbering altogether from 30 to 32 (Fig. 2, C).

*The large hooks* measure 148 to 153 μ in length and are provided with well-curved blades. The guard is situated at the posteriormost part of the anterior half of the hook, *i.e.*, towards the blade half. The base of the guard, viewed laterally, shows a slight constriction and a small distinct hump on its anterior edge, and its distal end is rounded. When viewed laterally the handle does not appear straight and shows a sort of hump dorsally; its distal end is tilted also to the same side giving the hook a characteritic appearance.

*The small hooks* measure 94 to 104 μ in length. The blade is strongly curved. The guard is situated in the anteriormost part of the posterior half of the total length of the hook. When viewed laterally it possesses a broad base and terminates distally in a rounded attenuated tip. Viewed ventrally the guard is about twice as wide distally as the main body of the hook. Just posterior to the guard and on the ventral side there is a characteristic elevation, rounded in outline and of about the same breadth as the handle. This elevation is not present in any of the small hooks of other species discussed in this paper. It is also neither mentioned nor figured in any published description of *M. serialis*. Viewed laterally the handle of this book shows a rounded distal end strongly tilted towards the dorsal side. Viewed ventrally the lateral edges of the handle are parallel.

### REFERENCES


Barion. 1933. Un cas de coenurose intermusculaire chez un lapin sauvage. Rec. de Med. Vet. [Paris] **109**: 166.

Baylis, H. A. 1932. On a coenurus from man. Trans. R. Soc. Trop. Med. and Hyg. **25**(4): 275.

Bonnal, G., Joyeux, C., and Bosch, P. 1933. Un cas de cénurose humaine du à *Multiceps serialis* (Gervais). Bull. Soc. Path. Exot. **26**: 1060.

Brumpt, E. 1913. Précis de Parasitologie. Paris.

———————, Duvoir, M. E., and Sainton, J. 1934. Un cas humaine du au *Coenurus serialis*, parasite habituel des lapins et des lievres. Ann. d. Parasitol. **12**: 371.

Clapham, Phyllis. 1940. Studies on *Coenurus glomeratus*. Jour. Helminth. **18**(1): 45.

———————— and Peters, B. G. 1941. The differentiation of *Coenurus* species by hook measurements. *Ibid.* **19**(34): 75.

Clapham, P. 1941. An English case of *Coenurus cerebralis* in human brain. *Ibid.* **19**(34): 84.

Christenson, R. O. 1929. A new cestode in the dog, *Multiceps packii* sp. nov. Jour. Parasit. **16**(1): 49.

Craig, C. F. and Faust, E. C. 1943. Clinical parasitology. London.

Ezzat, M. A. E. 1944. The occurrence of *Multiceps gaigeri* Hall, 1916 in subcutaneous connective tissue of Sudanese sheep and Nubian ibex. Egypt. Min. Agr., Vet. Serv. Bull. 238.

Faust, E. C. 1939. Human helminthology. London.
Geiger, S. H. 1907. *Coenurus serialis* found in two goats in India. Jour. Trop. Vet. Sci. [Calcutta] **2**: 316.
Hall, M. C. 1910. The gid parasite and allied species of the cestode genus *Multiceps*. I. Historical review. U. S. Bur. Anim. Indus. Bull. 125 [Washington].
————. 1910. Some important facts in the history of the gid parasite and their bearing on the prevention of the disease. *Ibid.* Circ. 159.
————. 1910. Methods for eradication of gid. *Ibid.* Circ. 165.
————. 1916. A new and economically important tapeworm *Multiceps gaigeri* from the dog. Jour. Amer. Vet. Med. Assoc., **50**, n.s. **3**(2): 214.
————. 1919. The adult taenioid cestodes of dogs and cats, and of related carnivores in North America. Proc. U. S. Natl. Mus. (2258) **55**: 1.
Henry, A. 1931. Les parasites et les maladies parasitaires du Rangodin. Bull. Soc. Nat. Acolim. [Paris] **78**: 431.
————. 1934. Observations sur les anomalies du scolex de *Multiceps serialis*. Ann. d. Parasitol. **12**: 384.
———— and Ciuca, A. 1914. Etude experimentale sur la cénurose du lapin. Ann. Inst. Pasteur. **28**: 365.
Hutyra, F., Marek, J., and Manninger, R. 1938. Special pathology and therapeutics of the diseases of domestic animals. London.
Joyeux, C. 1923. Note sure le *Multiceps spalacis* (Moniez, 1880). Ann Parasitol. **1**(1): 65.
Monnig, H. O. 1934. Veterinary helminthology and entomology. London.
Nagaty, H. F. 1940. On some larval cestodes from domesticated and laboratory animals. Jour. R. Egypt. Med. Assoc. **23**(5): 318–322.
Neveu-Lamaire, M. 1936. Traité d'helminthologie medicale et veterinaire. Paris.
Railliet, A. and Henry, A. 1915. Sur un cénurose de la gerbille à pieds velu. Bull. Soc. Path. Exot. **8**: 173.
———— and Mouquet, A. 1919. Cénure du coypou. Bull. Soc. Cent. Med. Vet. **72**: 205.
———— and Marullaz, M. 1919. Sur un cénure nouveau du bonnet chinois (*Macacus sinicus*). Bull. Soc. Path. Exot. **12**: 223.
Sandground, J. H. 1937. On a coenurus from the brain of a monkey. Jour. Parasitol. **23**(5): 482.
Schwartz, B. 1926. A subcutaneous tumour in a baboon due to *Multiceps* larvae. Jour. Parasitol. **12**(3): 159.
————. 1927. A subcutaneous tumour in a primate caused by tapeworm larvae experimentally reared to maturity in dogs. Jour. Arg. Research **35**(5): 471.
Sondhi, G. 1923. Tapeworm parasites of dogs in the Punjab. Parasitol. **15**(1): 59.
Sopikof, P. M. 1931. Eine seltene Localization von *Coenurus cerebralis* in den Muskeln eines Schafes. Tierärztl. Rundschau Friedenau **37**: 180.
Southwell, T. 1923. Notes on parasitic worms from the Gold Coast. Ann. Trop. Med. and Parasitol. **17**: 553.
————. 1930. The fauna of British India. Cestoda. vol. 2, p. 16.
Stevenson, E. C. 1904. Variation in the hooks of the dog tapeworms, *Taenia serrata* and *Taenia serialis*. Nebr. Univ., Studies from the Zool. Lab. No. 59.
Taramelli, N. and Dubois, A. 1931. Un cas coenurose chez l'homme. Ann. d. Soc. Belge. d. Med. Trop. **11**(2).
Turner, M. and Leiper, R. T. 1919. On the occurrence of *Coenurus glomeratus* in man in West Africa. Trans. Soc. Trop. Med. and Hyg. **13**: 23.
Yamaguti, S. 1935. Studies on the helminth fauna of Japan. Part 7. Cestodes of mammals and snakes. Japan. Jour. Zool. **6**: 239.

## Studies on filariasis. III. Potential mosquito vectors of *Wuchereria bancrofti*.

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### INTRODUCTION

When the first reports of filariasis in our troops were received, considerable concern was expressed over the possibility of various species of domestic mosquitoes

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of the United States serving as vectors for the filarial worms, *Wuchereria bancrofti* and *W. malayi*. It was anticipated that numbers of infected troops would return to the United States and that many of these would show microfilariae in the peripheral blood. Since to date only a small number have yielded microfilariae from the blood it now appears unlikely that there is any real danger of the transmission of filariasis in this country.

Early workers on experimental filariasis in this country include Wellman, von Adelung and Eastman (1910) who were unsuccessful in their attempts to infect mosquitoes, *Culex tarsalis* and *C. consobrinus* (=*C. pipiens*), and Francis (1919) who first demonstrated by feeding experiments that *Culex quinquefasciatus* (="*fatigans*") was a vector for *Wuchereria bancrofti*. Additional experiments on the mosquito vectors of filariasis are described by Newton and Wright (1944) and Newton, Wright and Pratt (1945). These authors report an extensive series of feeding experiments with various species and strains of mosquitoes collected from Puerto Rico and Alabama. Subsequently Scott, Richards and Seaman (1945) recorded the results of experimental feedings on mosquitoes indigenous to Southern California. The present report based upon experiments completed in 1944 furnishes additional data on potential vectors of this disease. All of the recent work in the United States (since 1944) appears to have been performed on periodic strains of *W. bancrofti* originating from the West Indies or South America.

## MATERIALS AND METHODS

Mosquitoes were infected by microfilariae of *W. brancrofti* from the peripheral blood of a volunteer who had lived in British Guiana a number of years prior to induction and was believed to have acquired the infection there. At no time previous to his coming to the United States had he been out of the Caribbean area. Hematoxylin-stained thick and thin smears, as well as fresh preparations, revealed the presence of microfilariae of *W. bancrofti*. In the experimental work the period of maximum production of microfilariae was determined for one or more days and/or nights and the mosquitoes were fed the following day at the same hour. Periodicity studies on this individual showed that the peaks of the microfilarial counts remained fairly constant under normal conditions. The approximate number of microfilariae present in the blood at the time of feeding varied from 3.5 to 5.0 per cmm. of blood.

Adult mosquitoes for the feeding experiments were secured from two sources. Some were collected as larvae in the field and reared from pupae; others came from the various strains maintained in the insectary of the Army Medical School.[3]

Several feeding methods were used: Some mosquitoes were placed in small glass globes, singly, or in groups of 2 to 4 mosquitoes. These globes were sealed at one end by rubber flaps and covered with gauze at the other. They were placed on the leg or arm of the volunteer, with the gauze-covered surface in contact with the skin. Feeding conditions were varied. Sometimes the volunteer was made to sweat profusely; at other times the globes were covered with dark cloth. The more timid mosquitoes were placed in a $24 \times 12 \times 12$-inch, gauze-covered cage. This was fitted with a sleeve through which the volunteer inserted his arm. In both cases a maximum exposure period of 1 hour was allowed.

In either case it was necessary to separate the mosquitoes that fed from the others, and the former group was liberated in a $24 \times 12 \times 12$-inch cage, dated and maintained in an environment of nearly constant temperature and humidity. Those mosquitoes which did not take a blood meal were destroyed at once.

[3] The assistance and cooperation of Capt. Curtis Saunders, SnC., of the Army Medical School, in furnishing laboratory-reared mosquitoes is gratefully acknowledged.

Mosquitoes dying overnight were dissected the following morning unless too dry or decomposed. Living mosquitoes taken for dissection were chloroformed and the legs and wings removed. The body was then divided into 3 sections, the head, thorax and abdomen, and each placed in a separate drop of water. Each of the three was examined and the location and developmental stages of the parasites carefully noted.

## RESULTS

A total of 1189 mosquitoes representing 5 species of *Aedes*, 2 of *Culex*, and 1 of *Anopheles* were exposed to the volunteer infected with a periodic (nocturnal) strain of *W. bancrofti;* 550 of these took a blood meal. Three of these eight species were found to serve as potential vectors (see Table 1).

TABLE 1.—*Summarizing development of W. bancrofti in several species of mosquitoes*

| Species | Number of exposures | Total number exposed | Total number that fed | Per cent that fed | Total positive | No. showing developing larvae before 10 days | No. showing infective larvae after 10 days | Maximum No. larvae per mosquito | Importance to man as pests |
|---|---|---|---|---|---|---|---|---|---|
| *Aedes aegypti* | 5 | 192 | 135 | 70.3 | 18 | 12 | 6 | 6 | 1 |
| *A. triseriatus* | 2 | 119 | 45 | 37.8 | ..... | ..... | ..... | ..... | 2 |
| *A. vexans* | 2 | 182 | 128 | 70.4 | ..... | ..... | ..... | ..... | 2 |
| *A. sollicitans* | 2 | 115 | 83 | 72.2 | ..... | ..... | ..... | ..... | 1 |
| *A. albopictus* | 2 | 101 | 36 | 35.6 | ..... | ..... | ..... | ..... | 1 |
| *Culex restuans* | 2 | 185 | 29 | 15.7 | 7 | 2 | 5 | 10 | 3 |
| *C. pipiens* | 3 | 166 | 43 | 25.9 | 13 | 1 | 12 | 12 | 1 |
| *Anopheles quadrimaculatus* | 1 | 129 | 51 | 39.5 | ..... | ..... | ..... | ..... | 1 |

Our observations on the ex-sheathing and subsequent moulting and development of the larvae parallel the descriptions given by Newton, Wright and Pratt (1945) and so will not be repeated here. It should be noted in passing that morphologically infective larvae were found in the hemocoele all the way from the abdomen to the proboscis. Experiments on the migration of these parasites in the mosquito were recorded previously by Newton and Pratt (1945).

## DISCUSSION

Of the 8 species (plus *A. punctipennis*) utilized in these experiments 3 fed well on the volunteer. Over 70 per cent of the *Aedes aegypti, A. vexans* and *A. sollicitans* which were exposed became engorged. These 3 species are known to attack man readily. Five other species, *Anopheles quadrimaculatus, Aedes triseriatus, A. albopictus, Culex pipiens* and *C. restuans* fed less voraciously. Of these only 39.5, 37.8, 35.6, 25.9 and 15.7 per cent respectively fed on the filariasis volunteer. Attempts to induce *A. punctipennis* to feed met with virtual failure.

Morphologically infective larvae of *W. bancrofti* were successfully recovered from 3 species of experimentally infected mosquitoes, *A. aegypti, C. pipiens* and *C. restuans.* Since *Aedes aegypti* was successfully infected by Newton, Wright and Pratt (1945) these data merely serve to confirm their findings. However, the infection of *C. pipiens* and *C. restuans* constitute new records of potential vectors of filariasis for the United States, as noted by Hunter and Harkema (1946). Negative results were secured by Wellman, von Adelung and Eastman (1910)

with *C. pipiens*, but other workers in Egypt, China and Japan have successfully infected one or more varieties of this species.

The infection of *Culex restuans* from the neighborhood of Washington, D. C., constitutes an entirely new record. This species is generally distributed throughout the northern, eastern and southern United States. It is interesting to note that *Culex restuans*, which is a potential vector of filariasis is a woodland breeding species which does not universally attack man. King, Bradley and McNeel (1942) found it a troublesome biter in Louisiana, although in Arkansas Thibault (1910) and Carpenter (1941) reported it to be less troublesome, except when present in large numbers. However, the fact that 7 of the 29 mosquitoes that fed were positive for active larvae suggests that in certain areas this species may be a dangerous vector. The positive findings on *C. restuans* are particularly interesting since Newton, Wright and Pratt (1945) were unable to get their Alabama strain of this species to feed.

Larvae of *C. restuans* were collected in the field, identified and then reared. Representative samples of both the larva and the adults were carefully checked.[4]

Negative results were secured with *Aedes albopictus*, which was imported in 1931 from the Philippines. This strain has been maintained in the insectary of the Division of Parasitology, at the Army Medical School.[5] Whether or not this strain of *A. albopictus* would serve as a vector for a diurnal or nocturnal periodic strain of *W. bancrofti* from the Philippines or of *W. malayi*, is not known at present.

It is interesting to note that laboratory-raised *Anopheles quadrimaculatus* did

TABLE 2.—*Species of mosquitoes demonstrated experimentally to be potential vectors of the periodic strain of Wuchereria bancrofti*

| Species | Authority |
|---|---|
| *Culex quinquefasciatus* | Newton, Wright and Pratt, 1945<br>Scott, Richards and Seaman, 1945 |
| *C. nigripalpus* | Newton and Wright, 1944<br>Newton, Wright and Pratt, 1945 |
| *Anopheles albimanus* | Newton and Wright, 1944<br>Newton, Wright and Pratt, 1945 |
| *Aedes aegypti* | Newton and Wright, 1944<br>Newton, Wright and Pratt, 1945<br>Hunter and Harkema (The present paper) |
| *A. triseriatus* | Newton, Wright and Pratt, 1945 |
| *Psorophora confinnis* (U. S.) | Newton, Wright and Pratt, 1945 |
| *P. confinnis* (P. R.) | Newton and Wright, 1944<br>Newton, Wright and Pratt, 1945 |
| *P. discolor* | Newton, Wright and Pratt, 1945 |
| *Culex erythrothorax* | Scott, Richards and Seaman, 1945 |
| *C. tarsalis* | Scott, Richards and Seaman, 1945[a]<br>Newton, Wright and Pratt, 1945 |
| *C. pipiens* | Hunter and Harkema (The present paper) |
| *C. restuans* | Hunter and Harkema (The present paper) |

[a] Insufficient data for a valid conclusion.

[4] The authors are indebted to Maj. L. S. West, SnC., Chief, Entomology Section, Division of Parasitology, Army Medical School, and to Dr. Alan Stone, U. S. National Museum, for these identifications.

[5] Because of the taxonomic changes in this complex, specimens were submitted in 1944 to Dr. Alan Stone of the U. S. National Museum who kindly verified the identification.

TABLE 3.—*Species of mosquitoes not yet demonstrated as being capable of serving as a vector of Wuchereria bancrofti*[a]

| Species | Authority |
|---|---|
| *Culex salinarius* | Newton, Wright and Pratt, 1945[b] |
| *C. erraticus* | Newton, Wright and Pratt, 1945 |
| *Anopheles quadrimaculatus* | Newton, Wright and Pratt, 1945<br>Hunter and Harkema (The present paper) |
| *A. punctipennis* | Newton, Wright and Pratt, 1945<br>Hunter and Harkema (The present paper)[d] |
| *Aedes vexans* | Newton, Wright and Pratt, 1945<br>Hunter and Harkema (The present paper) |
| *A. sollicitans* | Newton and Wright, 1944<br>Newton, Wright and Pratt, 1945<br>Hunter and Harkema (The present paper) |
| *A. taeniorhynchus* | Newton and Wright, 1944<br>Newton, Wright and Pratt, 1945<br>Scott, Richards and Seaman, 1945 |
| *A. triseriatus* | Hunter and Harkema (The present paper)[c] |
| *A. albopictus* | Hunter and Harkema (The present paper) |
| *Psorophora ciliata* | Newton, Wright and Pratt, 1945[d] |
| *Anopheles maculipennis* | Scott, Richards and Seaman, 1945[d] |
| *A. pseudopunctipennis* | Scott, Richards and Seaman, 1945[d] |

[a] *Culiseta incidens, C. inornata, C. stigmatosoma* would not feed (Scott, Richards and Seaman, 1945).

[b] Some contained advanced but not infective larvae.

[c] Newton, Wright and Pratt (1945) reported an infectibility percentage of 2.8 (see Table 2).

[d] Insufficient data for a valid conclusion.

not feed well on our volunteer. *Anopheles punctipennis* would seldom partake of a human blood meal, even though the volunteer was exposed to over 200 individual mosquitoes under varied conditions. Consequently this species is omitted from table 1.

These results when taken with those secured by Newton and Wright (1944), Newton, Wright and Pratt (1945) and Scott, Richards and Seaman (1945) indicate that 12 species should be regarded as potential vectors of *W. bancrofti* as shown in table 2.

In addition the species listed in table 3 were not infected successfully under the experimental conditions set up by the various authors. Species or strains of mosquitoes in which only immature, encapsulated or morphologically non-infective larvae were found, are also included in this table.

At the present time it cannot be stated how many of the mosquitoes which have been demonstrated as potential vectors for *W. bancrofti* would serve in a similar capacity for the diurnal (non-periodic) strain of *W. bancrofti* or for *W. malayi*.

## SUMMARY AND CONCLUSIONS

1. The authors have demonstrated that the following 3 species of mosquitoes indigenous to the United States may serve as vectors for *W. bancrofti, Aedes aegypti, Culex pipiens* and *C. restuans.*

2. *Culex restuans* and *C. pipiens* represent new potential vectors for *W. bancrofti.*

3. Laboratory-reared *Aedes albopictus,* originally imported from the Philip-

pines in 1931, would not serve as a vector for this strain of *W. bancrofti* under the conditions of the experiment.

4. Recent experiments by various authors indicate that 11 species of mosquitoes may serve experimentally as vectors of *W. bancrofti* and that at least 12 species have not as yet been shown experimentally to serve in this capacity.

LITERATURE CITED

CARPENTER, STANLEY J. 1941. The mosquitoes of Arkansas. Rev. Ed. Ark. State Board of Health, 87 pp.

FRANCIS, E. 1919. Filariasis in southern United States. U. S. Pub. Health Serv. Hyg. Lab. Bull. No. 117, June, 34 pp.

HUNTER, G. W., III, and HARKEMA, R. 1946. Studies on filariasis III. Potential mosquito vectors of *Wuchereria bancrofti*. Anat. Rec. **94**(3): 90. (Abstract.)

KING, W. V., BRADLEY, G. H., and MCNEEL, T. E. 1942. The mosquitoes of the southeastern states. U. S. Dept. Agr. Misc. Pub. No. 336 (Revised) Feb., 96 pp.

NEWTON, W. L., and WRIGHT, W. H. 1944. Tests to determine the ability of species of domestic mosquitoes to transmit *Wuchereria bancrofti*. J. Parasit. **36**(Suppl.): 11. [Abstract.]

———— and PRATT, I. 1945. Experiments to determine whether infective larvae of *Wuchereria bancrofti* can migrate from the abdomen of the mosquito intermediate host. J. Parasit. **31**(4): 266–268.

————, WRIGHT, W. H., and PRATT, I. 1945. Experiments to determine potential mosquito vectors of *Wuchereria bancrofti* in the continental United States. Amer. Jour. Trop. Med. **25**(3): 253–261.

SCOTT, O. K., RICHARDS, C. S., and SEAMAN, E. A. 1945. Experimental infection of southern California mosquitoes with *Wuchereria bancrofti*. J. Parasit. **31**(3): 195–197.

THIBAULT, JAMES K., JR. 1910. Notes on the mosquitoes of Arkansas (Diptera, Culicidae). Ent. Soc. Wash. Proc. **12**: 13–26.

WELLMAN, C., VON ADELUNG, E., and EASTMAN, FINLEY M. 1910. The relation of mosquitoes to filariasis in the region of San Francisco Bay. Jour. Amer. Med. Assoc. **55**(3): 217–218.

**A brief survey of the genus *Dictyocaulus* Railliet and Henry, 1907 (Nematoda: Trichostringylidae).** ELLSWORTH C. DOUGHERTY, Department of Zoology, University of California, Berkeley, California.

Since Railliet and Henry (1907) erected the genus *Dictyocaulus* for four species of lungworms from herbivorous mammals, namely *D. filaria* (Rudolphi, 1809) Railliet and Henry, 1907 (genotype), from the sheep and goat; *D. viviparus* (Bloch, 1782) Railliet and Henry, 1907, from the ox; *D. arnfieldi* (Cobbold, 1884) Railliet and Henry, 1907, from the horse and ass; and *D. noerneri* Railliet and Henry, 1907, from the roe deer (*Capreolus capreolus*), there have been but two[1] important review papers on the genus, one by Skriabin and Shul'ts (1934) and the other by Dikmans (1936a). The former considered all species described up to the time of their paper, but unfortunately their publication is not widely accessible, only one copy of the original being known to me in the entire United States. The latter, on the other hand, has considered in detail—in a readily accessible paper—only the morphology and synonymy of *D. viviparus*, with a few added notes on *D. filaria*. Other important contributions have been made, however. For example, Stroh (1940) has provided excellent drawings of the bursae of two species—*D. filaria* and *D. viviparus*. And in the past twenty-odd years several authors have described purportedly new species—*D. hadweni* Chapin, 1925, from several wild ruminants; *D. eckerti* Skriabin, 1931, from the reindeer (*Rangifer tarandus*); *D. unequalis* Bhalerao, 1932, from the Hodgson argali (*Ovis ammon hodgsoni*); *D. sibiricus* Orlov in Skriabin and Shul'ts, 1934, from the

[1] A third apparent review paper by Koffman (1942b) is not yet available in the United States.

domestic sheep; *D. khawi* Hsü, 1935, from the domestic pig; and *D. bisonis* Koffman, 1942, from the wisent (*Bison bison bonasus*); but none of these can withstand critical appraisal and have already in most cases been submerged as probable or definite synonyms. Those unrejected up to now are *D. sibiricus* and *D. bisonis*, which are herein regarded as synonyms of *D. filaria* and *D. viviparus* respectively.

In line with previous papers designed to bring up to date the nomenclature of mammalian lungworms (Dougherty, 1943, 1946, and others; Dougherty and Goble, 1946) the present work is a summary of the systematics of *Dictyocaulus*. Essentially it is supplementary to the paper by Dikmans (1936a).

Dikmans has recognized that *D. hadweni* is a synonym of *D. viviparus;* this conclusion was drawn after study of a large number of specimens belonging to the genus *Dictyocaulus* from several North American ruminants. Similarly he regarded *D. eckerti* and *D. khawi* as probable synonyms of the same species. Critical appraisal of the descriptions of these three supposed species shows that there is no consistent morphological difference between any one of them and *D. viviparus*. Furthermore, Skriabin and Shul'ts accepted *D. eckerti* as a synonym of *D. hadweni*, which Dikmans has clearly shown to be a synonym of *D. viviparus*. The latter worker has also accepted *D. unequalis* as a synonym of *D. filaria*.

Skriabin and Shul'ts, in accepting *D. sibicirus*, quoted the description thereof from a manuscript by N. P. Orlov, which, so far as I have been able to determine, has never been published. The Soviet helminthologists also accepted *D. unequalis* (which they emended to *D. unaequalis*) as a valid species and paraphrased Bhalerao's description (1932) in Russian translation. There is no evidence from their paper that they examined specimens identified by Orlov or by Bhalerao as belonging to one or the other of the two supposed species. I find no consistent morphological criterion from Orlov's diagnosis as quoted by Skriabin and Shul'ts by which *D. sibicirus* can be separated from *D. filaria*.

*D. bisonis* as described and figured by Koffman (1942a) has no obvious morphological difference from *D. viviparus*. All measurements fall within the range already known for specimens of *D. viviparus*. There can be little doubt that Koffman's specimens belonged to the last-named species.

Strangely enough the only species described since the genus *Dictyocaulus* was instituted that can, I feel, be regarded as a valid member thereof is *Bronchonema magnum*[2] Mönnig, 1932, emend. nov., originally named from the Blesbok (*Damaliscus albifrons*). Skriabin and Shul'ts accepted the genus *Bronchonema* Mönnig, 1932, but Böhm and Gebauer (1934) pointed out that it should actually be regarded as a synonym of *Dictyocaulus*. However, the single species of the former genus has not hitherto been formally transferred to the latter with the formation of a new combination of generic and trivial names—*i.e.*, *Dictyocaulus magnus* (Mönnig, 1932), comb. nov.

Aside from new treatment of *D. sibiricus*, *D. bisonis*, and *B. magnum* the present paper can also dispose of the species *D. noerneri*, which is truly the orphan of its genus, for almost no one has paid it any particular attention since its erection in 1907. It was mentioned by Brumpt (1911) in a non-taxonomic paper and has been cited in several compendia. Skriabin and Shul'ts considered it a *species inquirenda*. Railliet and Henry based their species on an organism discussed by Nörner (1881) and recorded by him from the roe deer ("Reh") as *Strongylus filaria*. If the latter's figures, which are of the spicules only, are examined critically, it can be seen that they clearly resemble those of *D. viviparus*. In view of the fact that the measurements given by Nörner, *i.e.*, 281 μ, fall within the range

[2] Given ungrammatically as *Bronchonema magna* by Mönnig (1932) and hitherto uncorrected.

found by Dikmans (1936a) there seems no serious doubt that *D. noerneri,* like *D. hadweni* and *D. eckerti,* which were described from other cervids, is also a synonym of *D. viviparus.*

Skriabin and Shul'ts divided *Dictyocaulus* into two subgenera, *Dictyocaulus* and *Micrurocaulus.* The latter, a new name, was attributed by them to Skriabin alone, presumably to an unpublished manuscript although this is not included in their list of references along with several other cited manuscripts, mostly in the files of the Vsesoiuznyĭ Institut Gel'mintologii, Moscow. The only given point of distinction was that the medio- and posterolateral rays in the former subgenus are only partly united, whereas they are fused along their entire length in the latter subgenus. Of the species accepted by me only *D. viviparus* falls into *Micrurocaulus.* There seems no advantage in retaining this subdivision for only one species on the basis of what is a relatively unimportant character.

To summarize it appears that there are four acceptable species of *Dictyocaulus* known to date—*D. filaria, D. viviparus, D. magnus,* and *D. arnfieldi.* Of these *D. filaria* is found principally in sheep and goats, both domestic and wild (family Bovidae, subfamily Caprinae), and *D. viviparus* in cattle and bison (subfamily Bovinae) and many deer-like ruminants (family Urvidae). However, *D. filaria* occurs in cervids as shown, among others, by Dikmans (1935) for North America and by Wetzel and Enigk (1937) for Europe. Kotlán (1939) in a short but excellent report and discussion on host-specificity in lungworms, particularly of ruminants, was able to show definitely that both *D. filaria* and *D. viviparus* occur in the "camel"—probably *Camelus bactrianus* (family Camelidae). *D. magnus* has so far been found in two antelopes only (family Bovidae)—the Blesbok (*Damaliscus albifrons,* subfamily Hippotraginae) by Mönnig (1932) and the Springbok (*Antidorcas marsupialis* ?subsp., subfamily Antilopinae) by Dikmans (1936b). The remaining species, *D. arnfieldi,* is restricted to members of the order Perissodactyla —to equines (horse, ass and zebra, family Equidae) and the Indian tapir (*Tapirus indicus,* family Tapiridae). Since the other three species of *Dictyocaulus* occur exclusively, yet widely, in ruminants (except the questionable report of *D. khawi* [=*viviparus*] from the pig) which belong to the order Artiodactyla, it would not seem unlikely that *D. arnfieldi* was secondarily acquired by members of the order Perissodactyla from ancestors in ruminants.

Of the four species of *Dictyocaulus* specimens of all but *D. magnus* have been available to me. In addition to acknowledgments already made in an earlier paper (1945a) I am indebted to Dr. Niels Dungal, Rannsóknostofa Háskólans (Department of Pathology, University of Iceland), Reykjavík, for numerous specimens of *D. filaria* from Icelandic sheep and to Dr. E. W. Price, Zoölogical Division, United States Bureau of Animal Industry, Beltsville, Maryland, for specimens of *D. arnfieldi.*

The species of *Dictyocaulus* are herein listed under their genus with their synonyms and type hosts. Where names are here reduced to synonymy for the first time, they are marked with an asterisk (*). In the list of references at the end of the paper are given the titles of papers where all new names and combinations first appeared even if not cited elsewhere in the text. The genus *Dictyocaulus* is to be placed (in following Dougherty, 1945b) in the subfamily Skrjabingylinae Skriabin, 1933, of the family Trichostrongylidae Leiper, 1912, and suborder Strongylina Pearse, 1936.

**Dictyocaulus** Railliet and Henry, 1907.

Synonymy.—*Strongylus* Müller, 1780 (*partim*); *Bronchonema* Mönnig, 1932; *Dictyocaulus* (Railliet and Henry, 1907) Skriabin in Skriabin and Shul'ts, 1934 (subgenus); **Micrurocaulus* Skriabin in Skriabin and Shul'ts, 1934 (subgenus).

GENOTYPE.—*D. filaria* (Rudolphi, 1809) Railliet and Henry, 1907 (type by original designation).

SPECIES.—

**Dictyocaulus filaria** (Rudolphi, 1809) Railliet and Henry, 1907.

SYNONYMY.—*Strongylus filaria* Rudolphi, 1809; *Sclerostomum filaria* (Rudolphi, 1809) Braun and Lühe, 1910; *Dictyocaulus unequalis* Bhalerao, 1932; *Dictyocaulus unaequalis* Bhalerao, 1932, emend. Skriabin and Shul'ts, 1934; **Dictyocaulus sibericus* N. P. Orlov in Skriabin and Shul'ts, 1934; *Dictyocaulus* (*Dictyocaulus*) *filaria*, of Skriabin and Shul'ts, 1934; *Dictyocaulus* (*Dictyocaulus*) *sibiricus*, of Skriabin and Shul'ts, 1934; *Dictyocaulus* (*Dictyocaulus*) *unaequalis*, of Skriabin and Shul'ts, 1934.

TYPE HOST.—Domestic sheep, *Ovis aries* Linné.

**Dictyocaulus viviparus** (Bloch, 1782) Railliet and Henry, 1907.

SYNONYMY.—*Ascaris filiformis cauda rotundata* Goeze. 1782; *Gordius viviparus* Bloch, 1782; *Ascaris vituli* Gmelin, 1790; *Fusaria vituli* (Gmelin, 1790) Zeder, 1803; *Strongylus vitulorum* Rudolphi, 1809; *Strongylus micrurus* Mehlis in Gurlt, 1831; *Strongylus filaria* in "Reh," of Nörner, 1881; **Dictyocaulus nocrneri* Railliet and Henry, 1907; *Metastrongylus micrurus* (Mehlis in Gurlt, 1831) Sluiter and Swellengrebel, 1912; *Dictyocaulus micrurus* (Mehlis in Gurlt, 1831) Railliet, 1915; *Dictyocaulus hadweni* Chapin, 1925; *Dictyocaulus eckerti* Skriabin, 1931; *Dictyocaulus* (*Micrurocaulus*) *viviparus*, of Skriabin and Shul'ts, 1934; *Dictyocaulus* (*Micrurocaulus*) *hadweni*, of Skriabin and Shul'ts, 1934; *Dictyocaulus khawi* Hsü, 1935; **Dictyocaulus bisonis* Koffman, 1942.

TYPE HOST.—Domestic ox, *Bos taurus* Linné.

**Dictyocaulus magnus** (Mönnig, 1932), comb. nov.

SYNONYMY.—*Bronchonema magna* Mönnig, 1932; *Bronchonema magnum* Mönnig, 1932, emend. nov.

TYPE HOST.—Blesbok, *Damaliscus albifrons* (Burchell).

**Dictyocaulus arnfieldi** (Cobbold, 1884) Railliet and Henry, 1907.

SYNONYMY.—*Strongylus arnfieldi* Cobbold, 1884; *Metastrongylus arnfieldi* (Cobbold, 1884) Sluiter and Swellengrebel, 1912; *Strongylus* (*Dictyocaulus*) *arnfieldi*, of Hutyra and Marek, 1913; *Dictyocaulus* (*Dictyocaulus*) *arnfieldi*, of Skriabin and Shul'ts, 1934.

TYPE HOST.—Domestic ass, *Equus asinus* Linné.

## REFERENCES

BHALERAO, G. D. 1932. On some nematode parasites of goats and sheep at Muktesar. Indian Jour. Vet. Sci. and Anim. Husb. 2(3): 242–254, pls. 17–20.

BLOCH, M. E. 1782. Abhandlung von der Erzeugung der Eingeweidewürmer und den Mitteln wider dieselben. Eine von der Königlich Dänischen Societät der Wissenschaften zu Copenhagen gekrönte Preisschrift. 54 pp., 10 pls. Berlin.

BÖHM, L. K., and GEBAUER, O. 1934. Zum System der Familie der Mestastrongylidae Leiper, 1908. Zool. Anz. **105**(11/12): 287–294.

BRAUN, M. G. C. C., and LÜHE, M. F. L. 1910. A handbook of practical parasitology. Translated by Linda Forster. 208 pp., 100 figs. London.

BRUMPT, E. J. A. 1911. Les cerfs de la forêt de Chantilly sont décimés par les helminthes. Comp. Rend. Acad. Sci., Paris **152**(13): 906–909.

CHAPIN, E. A. 1925. New nematodes from North American mammals. Jour. Agr. Res. 30(7): 677–681, 4 figs.

COBBOLD, T. S. 1884. New parasites from the horse and ass. Veterinarian **57**[4s., **30**], no. 349, pp. 4–7.

DIKMANS, D. 1935. Lungworms collected from deer, *Odocoileus virginianus*, in Michigan. Proc. Helminth. Soc. Wash. 2(1): 59.

————————. 1936a. A note on *Dictyocaulus* from domestic and wild ruminants. Jour. Wash. Acad. Sci. **26**(7): 298–303, 1 fig.

————————. 1936b. The springbuck, *Antidorcas marsupialis*, a new host of the lungworm, *Bronchonema magna* Mönnig, 1932 (Nematoda: Metastrongylidae). Proc. Helminth. Soc. Wash. **3**(2): 64.

Dougherty, E. C. 1943. Notes on the lungworms of porpoises and their occurrence on the California coast. *Ibid.* **10**(1): 16–22.

————————. 1945a. The nematode lungworms (suborder Strongylina) of North American deer of the genus *Odocoileus*. Parasitology **36**(3/4): 199–208, 11 figs.

————————. 1945b. A review of the genus *Crenosoma* Molin, 1861 (Nematoda: Trichostrongylidae); its history, taxonomy, adult morphology, and distribution. Proc. Helminth. Soc. Wash. **12**(2): 44–62, 3 figs.

————————. 1946. The genus *Aelurostrongylus* Cameron, 1927 (Nematoda: Metastrongylidae), and its relatives; with descriptions of *Parafilaroides*, gen. nov., and *Angiostrongylus gubernaculatus*, sp. nov. *Ibid.* **13**(1): 16–25, 2 figs.

————————, and Goble, F. C. 1946. The genus *Protostrongylus* Kamenskiĭ, 1905 (Nematoda: Metastrongylidae), and its relatives: preliminary note. Jour. Parasitol. **32**(1): 7–16.

Gmelin, J. F. 1790. Caroli à Linné. . . . Systema naturae per regna tria naturae, secundum classes, ordines, genera, species cum characteribus differentiis, synonymis, locis. Vol. 1, pt. 6 [Vermes], pp. 3021–3910.

Hsü, H. F. 1935. A study of some Strongyloidea and Spiruroidea from French Indo-China and of *Thelazia chungkingensis* Hsü, 1933 from China. Ztschr. f. Parasitenk. **7**(5): 579–600, 31 figs.

Hutyra, F., and Marek, J. 1913. Spezielle Pathologie und Therapie der Haustiere. Vol. 2, Krankheiten der Atmungsorgane, der Verdauungsorgane, des Nervensystems, der Bewegungsorgane und der Haut. 4th Ed., xvi + 1088 pp., 207 figs., 7 pls. Jena.

Koffman, M. 1942a. Bidrag till kännedomen of parasiter hos husdjur och vilt i Sverige. III. Parasitfaunan hos bisonoxe, visent (*Bison Europeus*). Skandin. Vet.-tidsk. **32**(3): 150–192, 26 figs.

————————.[3] 1942b. Om lungparasiter tillhörande släktet *Dictyocaulus*. Svensk Vet.-tidsk. for 1942, pp. 577–?.

Kotlán, A. 1939. Zur Frage der Wirtspezifizität der Lungenwürmer. Zentbl. f. Bakt. [etc.] Abh. I, Orig. **144**(7/8): 411–416.

Leiper, R. T. 1912. Check list of helminths parasitic in cattle (*Bos taurus, Buffelus indicus, Bibos indicus*). Jour. London School Trop. Med. **11**(2): 115–122.

Mehlis, E. 1831. In: Gurlt, E. F. Lehrbuch der pathologischen Anatomie der Haus-Säugethiere nebst einem Anhange welcher die Beschreibung der bei den Haus-Säugethieren vorkommenden Eingeweidewürmer enthält. Pt. 1, 399 pp. Berlin.

Mönnig, H. O. 1932. Wild antelopes as carriers of nematode parasites of domestic ruminants—part II. Rpt. Dir. Vet. Serv. and Anim. Indus., Union So. Africa **18**: 153–172, 27 figs.

Müller, O. F.[4] 1780. Zoologiae danicae seu animalium Daniae et Norvegiae rariorum ac minus notorum icones. Pt. 2, pls. 41–80. Havniae.

Nörner, C. 1881. Zur Kenntnis der Spicula der Strongyliden. Österr. Monatschr. Thierheilk. **5**(1): 2–5, 30 figs.

Pearse, A. S. 1936. Zoölogical names a list of phyla, classes, and orders. 24 pp. Durham, North Carolina.

Railliet, L. J. A. 1915. L'emploie des médicaments dans le traitement des maladies causées par des nématodes. Recueil Méd. Vét. **41**(5): 490–513. (Also in: Rpt. 10th Internatl. Vet. Cong. **3**: 733–749.)

————————, and Henry, A. C. L. 1907. Sur les variations des strongyles de l'appareil respiratoire des mammifères. Comp. Rend. Soc. Biol. [Paris] **63**(38): 751–753.

Rudolphi, K. A. 1809. Entozoorum sive vermium intestinalium historia naturalis. vol. 2, pt. 1, 457 pp., pls. 7–12. Amstelaedami.

Skriabin, K. I. 1931. Glistnye invazii severnogo olenia. 88 pp., 54 figs., 1 pl. Moscow-Leningrad.

[3] Not seen; see footnote 1.

[4] In footnote number 7 in the bibliography of a recent paper (Dougherty and Goble, 1946) this publication was qualified as "apparently not available in North America"; it has, however, been subsequently found in the library of the University of Minnesota.

———— (i.e., Skriabine, K. I.). 1933. Sur la position systématique des nématodes du genre *Oslerus* Hall, 1921. Bull. Soc. Zool. France **58**: 87–89.
————, and SHUL'TS, R. E. S. 1934. Diktiokaulezy domashnikh zhivotnykh i meri bor'bi s nimi. (Monograficheskiĭ etiud.) 56 pp., 2 figs., 3 pls. Moscow.
SLUITER, C. P., and SWELLENGREBEL, N. H. 1912. De dierlijke parasieten van den mensch en van onze huisdieren. 2nd Ed., xvi + 520 pp., 262 figs., 1 pl. Amsterdam.
STROH, G. 1940. Zum Bau der männlichen Wurmenden von *Dictyocaulus filaria* und *D. viviparus*. Berlin u. München. Tierärztl. Wchnschr. **1940**(35): 422–423, 4 figs.
WETZEL, R., and ENIGK, E. 1937. Ein weitere Beitrag zur Lungenwurmfauna des Hochwildes. Sitzber. Gesell. f. Naturf. Freunde, [Berlin] **1937**(1): 9–10.
ZEDER, J. G. H. 1803. Anleitung zur Naturgeschichte der Eingeweidewürmer. xvi + 432 pp., 4 pls. Bamberg.

**Further studies on the life history of the golden nematode of potatoes (*Heterodera rostochiensis* Wollenweber), season 1945.** B. G. CHITWOOD and EDNA M. BUHRER, U. S. Bureau of Plant Industry, Soils and Agricultural Engineering, Hicksville, N. Y., and Beltsville, Md.

An account of the life history of the golden nematode of potatoes (*Heterodera rostochiensis* Wollenweber) under Long Island, N. Y., conditions, has been published (Chitwood and Buhrer: Phytopathology **36**(3): 180–189, 1946). Data for that report included observations through the season 1944. Several salient points were brought out, briefly:

1. The entire life cycle (from embryonated eggs to embryonated eggs) is not less than 38 nor more than 48 days.

2. In 1944 larvae were first seen in potato roots shortly after the soil temperature had risen suddenly to a weekly mean of 59° F. following a 3-week period with weekly means of 49 to 51° F. Evidence in previous years has indicated nematode dormancy at weekly mean temperatures up to 54° F., but there was no such period in 1944.

3. The potato variety Irish Cobbler grew at soil temperatures as low as 45 to 58° F., *i.e.*, it was able to grow before mass root invasion by *H. rostochiensis* occurred; the variety Green Mountain, however, began to grow when soil temperatures reached 54 to 58° F. Varietal difference in susceptibility to nematode damage between Green Mountain and Irish Cobbler is probably due to the ability of Irish Cobbler to produce roots at temperatures below those at which nematode attack takes place; it is highly probable that the same applies to other varieties. Differences in injury from year to year within a given variety probably depend upon the duration of those temperatures when the plants can grow free of nematode attack.

During the 1945 season an effort was made to arrive at more exact data concerning the conditions that bring about nematode invasion of the roots of the Green Mountain potato, again under conditions prevailing on Long Island, N. Y. On March 30 potatoes of the var. Green Mountain were planted in experimental plots. At 8 successive dates during the growing season, 8 plants from each of 5 plots were dug as carefully as possible and their roots preserved. Weighed samples of roots of these preserved plants were then dissected, the nematodes counted, and the number of specimens of *H. rostochiensis* for the entire root system computed. Table 1 gives the result of this work. We should note here that a uniform pattern was used throughout the collecting of plants in the various plots so that personal selection would have no influence, and a uniform method of digging was employed; no attempt was made to obtain all the roots, only those roots which conveniently remained attached to the stem being taken.[1]

[1] The maximum number of *H. rostochiensis* estimated on any plant taken this season (not, however, from the experimental plot described above) was 40,000, collected June 4.

TABLE 1.—*Mean numbers and stages of golden nematodes per plant, from roots of potatoes (var. Green Mountain), at various dates*

| Date, 1945 | Temperatures, 2 previous weeks, °F. (mean) | No. nematodes attached to roots | No. nematodes loose in staining fluid[a] | Stages of development[b] |
|---|---|---|---|---|
| April 30 | 52; 52 | 11 | 0 | 1st |
| May 7 | 52; 51 | 161 | 0 | 1st,* few molting |
| May 21 | 52; 60 | 1217 | 0 | 1st, 2nd, 3rd,* 4th |
| June 4 | 61; 57 | 12109 | 220 | 1st, 2nd, 3rd,* 4th* |
| June 18 | 59; 77 | 4487 | 1664 | 1st, 2nd, 3rd,* 4th,* eggs |
| July 2 | 75; 77 | 2000 | 355 | 1st, 2nd, 3rd, 4th, eggs* |
| July 7 | 77; 76 | 957 | 128 | 1st, 2nd, 3rd, 4th, eggs* |
| July 25[c] | 70; 74 | 750 | 530 | 1st, 2nd, 3rd, 4th, eggs, pits* |

[a] Specimens that had been dislodged from roots by manipulation.

[b] 1st, 2nd, etc. = 1st stage larva, 2nd stage larva, etc. Eggs = presence of gravid females or of cysts, containing eggs. Pits = pits, or cavities left where mature females had previously been attached.

[c] Data obtained by vigorous shaking and washing of roots to dislodge nematodes.

* Predominant stage found.

The table shows a minor nematode invasion of the roots in periods having a weekly mean temperature of 51 to 52° F. and mass invasion at 60 to 61° F.; it can safely be said that little or no development of the nematode takes place at 52° F. It was interesting to note that larvae apparently entered the roots during an early warm week, April 9, at which time the mean temperature exceeded 59° F., but that they did not continue their development further, until temperatures rose. As the females mature there is an increasing tendency for them to become dislodged and drop off when the roots are disturbed, and we interpret the decline in numbers, beginning June 18, as a manifestation of this tendency. Late in the season the very act of removing plants from the soil dislodges hundreds if not thousands of specimens.

More complete data were taken during the 1945 season than previously, on the

TABLE 2.—*Growth of potato plants (var. Green Mountain) on soil infested with the golden nematode as compared with that on uninfested[a] soil. Each weight is the mean, in grams, of 40 plants, i.e., 8 plants from each of 5 replicated plots*

| Date | Infected plants (grown on untreated soil) | | | | Uninfected plants (grown on treated soil) | | | |
|---|---|---|---|---|---|---|---|---|
| | Tops | Roots | Tubers | Total wt. | Tops | Roots | Tubers | Total wt. |
| May 7 | 8.14 | 2.96 | 0 | 11.1 | 9.02 | 2.82 | 0 | 11.8 |
| May 21 | 43.98 | 4.90 | 0.92 | 49.8 | 47.70 | 4.92 | 1.58 | 54.2 |
| June 4 | 184.40 | 8.88 | 18.2 | 211.5 | 233.42 | 7.34 | 45.50 | 286.3 |
| June 18 | 234.00 | 5.82 | 127.0 | 367.2 | 347.60 | 6.70 | 235.00 | 589.3 |
| July 2 | ..... | ..... | 265.0 | ..... | ..... | ..... | 307.00 | .. |
| July 7 | 298.20 | 5.24 | 273.0 | 576.4 | 364.60 | 4.64 | 415.80 | 785.0 |
| July 19 | ..... | ..... | 279.0 | ..... | ..... | ..... | 430.00 | ..... |
| Aug. 6–13 | . | .... | 350.0 | . . | . . | ... | 507.00 | . |

[a] Plots had been treated with D–D, which had eradicated from the soil 94 per cent of the parasites. (Results of these treatments from the standpoint of disease control to be published elsewhere.)

effect of the nematodes upon growth of the potato plants (Table 2). Readings for this study were made on the infected plants of 5 of the 8 digging dates described in table 1; 3 additional weight readings were made on tubers only, as shown in table 2. For comparison, growth readings were made on uninfected plants on the same dates. Data on both infected and uninfected plants have been condensed into the means by date, based on 8 plants, 5 replications per date.

In an analysis of the table certain generalizations appear to be in order:

1. Growth of tops: No appreciable difference between infected and uninfected plants through May 21; thereafter infected plants show stunting.

2. Growth of roots: No difference through May 21; thereafter, some increased growth in infected plants (a phenomenon frequently observed in root systems attacked by other nematodes as well and conceived by some workers to be "reparative" growth), followed by decline in weight in both infected and uninfected plants.

3. Growth of tubers: More rapid on uninfected plants, the difference, slight at first, becoming most pronounced during the periods May 21 to June 4 and June 18 to July 7.

Comparing the records of the 1944 and 1945 seasons, we note a marked contrast in the effect of golden nematode on potato root growth. There was a decided early suppression of root growth in 1944 on heavily infested land, and no such occurrence in 1945. In 1944 the weekly mean temperature jumped from 49 to 59° F., and it was at some time during that period that root growth began. In 1945, on the other hand, there were 4 weeks of 51 to 52° F. mean temperature when root growth was established and continued unimpeded. Thus a more specific temperature record is set for growth of the var. Green Mountain. As mentioned earlier, mass invasion of the roots by *H. rostochiensis* occurred at 60 to 61° F. weekly mean temperature.

**Further observations on the nature of anaplasma.** JOHN C. LOTZE, U. S. Bureau of Animal Industry.

Multiplication of the "coccus-like" parasites found in the red blood cells of cattle affected with the disease anaplasmosis has been commonly thought to take place through the process of binary fission. In a previous report Lotze and Yiengst (1942, Amer. Jour. Vet. Res. 3(8): 312–320) presented certain evidence to show that each parasite or anaplasm undergoes growth, followed by some type of division which results in the formation of 8 small spherical bodies. Because anaplasms showing what might be considered as 2- and 4-celled stages could not be demonstrated, it was assumed that the parasites undergo multiple fission. However, it was not possible to demonstrate stages which would lend support to this view.

In studies of drug therapy in anaplasmosis, approximately 250 milligrams of potassium arsenite and 100 milligrams of acriflavine dissolved in 50 cc. of distilled water were administered intravenously, on each of 3 consecutive days, to an infected calf weighing 295 pounds. The calf died on the third day after treatment was begun. An examination of blood smears, made on each of the 2 days following the first treatment, showed that the protoplasmic material of many anaplasms was arranged around a clear central space, as shown in figure 1. This material was not arranged so as to form a smooth ring, but was thicker and appeared to be denser in certain areas than in others. In certain of the smaller anaplasms, two areas of thickened material were noted; in the larger forms, the protoplasmic material was often thickened in 4 areas. In addition to these structures, small spherical bodies arranged in the various configurations, described in the previous report (*loc. cit.*), were observed.

To determine whether these abnormalities could be reproduced, approximately 500 mg. of potassium arsenite and 500 mg. of acriflavine dissolved in 50 cc. of

distilled water, were administered intravenously to an infected animal which weighed 817 pounds. In the 2 consecutive days following treatment, no appreciable changes in the anaplasms were noted. Consequently, approximately 750 mg. of potassium arsenite and 300 mg. of acriflavine dissolved in 75 cc. of distilled water were then administered on the second day after the first treatment. Configurations similar to those described for the anaplasms in the first case were observed in the blood smears of this host on the second day after the last treatment; at this time the host was in a moribund condition.

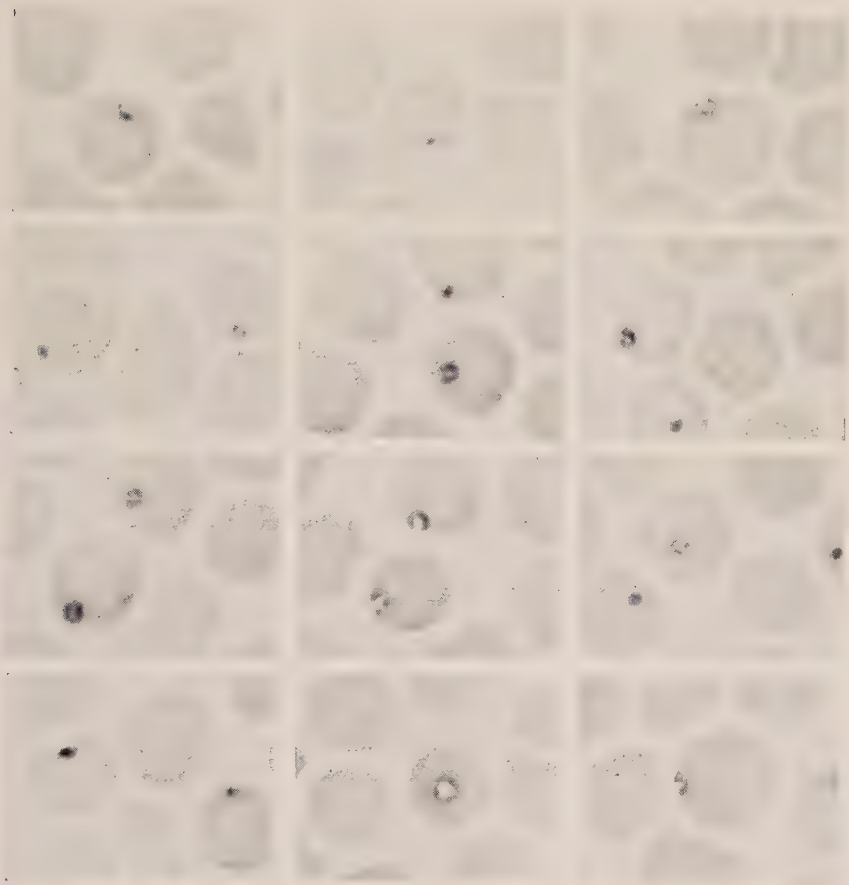

FIG. 1.—Photomicrographs of parasitized red blood cells from an experimental infection of *Anaplasma marginale* treated with potassium arsenite and acriflavine.

The interpretation given by the writer to the abnormal structures observed in the blood smears is that, because of the treatment administered to the host, the protoplasmic material of the anaplasms was affected in some manner during the process of multiple fission. As in previous studies, no evidence was found for binary fission.

**A fatal case of *Trichomonas gallinae* infection in a nestling mourning dove.** PAUL D. HARWOOD, Ashland, Ohio.

Within the city limits of Ashland, two nestling mourning doves, *Zenaidura macroura carolinensis,* were found May 19, 1944, on the ground beneath the nest.

One was already dead, the other was weak when found. The presence of an obstruction in the esophagus was detected when attempts were made to feed the nestling by hand. However, a small amount of food was forced into the crop.

The nestling was obviously moribund on the morning of May 20. At necropsy a large yellowish, necrotic mass was found in the upper esophagus. Other smaller areas occurred lower in that organ and crop. Scrapings of the crop were teeming with active Trichomonas when examined under the microscope.

On May 22, 1944, the author was shown another nestling dove which reportedly was discovered when the parent dove was found dead underneath the nest. Again the nestling's mate was already dead and the nestling died within 24 hours in spite of every effort to care for it. Unfortunately none of these birds was submitted to necropsy.

Since Stabler (1946, Jour. Parasitol. **31**(suppl.): 7–8 and earlier) has shown that *Trichomonas gallinae* is an extremely pathogenic parasite of a variety of birds, it seems probable that the nestling submitted to necropsy died of this infection. Possibly, therefore, other mourning doves reported dying in the same vicinity were destroyed by the same parasite. Whether these few data, collected casually, indicated heavy mortality among mourning doves of the vicinity, or only a limited loss must remain conjectural.

## MINUTES

*Two Hundred Fifty-third to Two Hundred Sixtieth Meetings*

The 253rd meeting was held October 17, 1945, at the U. S. National Museum. Dr. E. Caballero y C was elected to membership. Papers were presented by Steiner, Dikmans, Spindler and Otto.

The 254th meeting was held November 21, 1945, at the Plant Industry Station, Beltsville, Maryland. Dr. H. E. Ewing was elected to life membership. Dr. J. R. Christie was reelected to serve for five years on the Editorial Committee. Article 10, Section 1 of the By-Laws was amended to include the Recording Secretary on the Executive Committee. Papers were presented by Hunter, Machmer and Otto.

The 255th meeting was held December 17, 1945, at the U. S. National Museum. Dr. M. Mollari was elected to represent the Society in the Washington Academy of Sciences. The following officers were elected: President, T. Von Brand; Vice-president, G. W. Hunter III; Corresponding Secretary-treasurer, E. M. Buhrer; Recording Secretary, M. M. Farr. Papers were presented by Habermann and Chitwood.

The 256th meeting was held at Catholic University on January 16, 1946. Mr. J. Bozicevich was appointed to the Executive Committee. Papers were presented by Spindler and Reinhard.

The 257th meeting was held February 19, 1946, at the U. S. National Museum. The report of the Auditing Committee was adopted. The following members presented papers: Chitwood, Otto and Von Brand. Dr. J. R. Christie presented a memorial on the death of Dr. Henry B. Ward. The Society authorized the publication of this memorial in the minutes.

> The Helminthological Society of Washington learns with deep regret of the death of Dr. Henry Baldwin Ward. Dr. Ward was made a corresponding member of the Society at its 6th meeting, April 11, 1911, and an honorary member at its 157th meeting, October 21, 1933. In recalling Dr. Ward's life with a view to noting some of his outstanding achievements one finds many from which to choose. We might think of him as a member of the faculty of a great university and of his services in administering the affairs of that institution, especially of his own depart-

ment of zoology. We might recall the offices he has held in numerous scientific societies and his influence in shaping the policies and assuring the success of these organizations. These and many similar services were the results of an active, varied, and successful administrative career. Recognition must be given to his achievements as an editor. Largely through his initiative and ability both the Journal of Parasitology and the Illinois Biological Monographs became available as mediums of publication. The results of his own research are found in his numerous papers and the contribution is a very substantial one. However, it was not in editing the papers of others and providing for their publication, or even in writing his own, that Dr. Ward made his greatest contribution to Parasitology. Through the outstanding success of his graduate school, due largely to his ability in training graduate students, Dr. Ward succeeded in promoting study and research in Parasitology to an extent that has few parallels in the annals of American education. To Dr. Ward the teacher we pay special tribute. To the members of his family the Society extends its sincerest expression of sympathy.

The 258th meeting was held March 20, 1946, at the National Institute of Health, Bethesda, Maryland. A committee was appointed to investigate the possibility of the purchase of the whole Henry B. Ward library by the American Society of Parasitologists. Two motion picture films were shown, the first a confiscated Japanese film on schistosomiasis and the second a film on the story of phenothiazine.

The 259th meeting was held April 17, 1946, at the U. S. National Museum. The report of the committee for investigating the purchase of the H. B. Ward library was presented. The time of the December meeting was changed from the third week to the second week of that month. A paper was presented by Dr. Lotze.

The 260th meeting was held May 25, 1946, in conjunction with the annual picnic at the Log Cabin, Beltsville Research Center, Beltsville, Maryland. Miss M. J. Raecke and Mrs. V. Files were elected to membership. The Society voted to continue the present system of holding meetings.

MARION M. FARR,
*Recording Secretary*

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